AN INTRODUCTION TO SCHOLAR TEAMS: A METHOD TO ENHANCE DSP EDUCATION AND COMPETENCE

Roger A. Green

ECE Department, North Dakota State University, Fargo, ND 58105-5285
Phone: 701.231.1024, E–mail: Roger.Green@ndsu.edu.

ABSTRACT

This paper introduces the concept of Scholar Teams (STs), discusses strategies to successfully implement STs, overviews the results of the first two years of comprehensive ST trials conducted in the Electrical and Computer Engineering (ECE) department at North Dakota State University (NDSU), and details a specific ST, the Digital Signal Processing (DSP) ST, to illustrate the benefits of STs, particularly from a DSP education perspective.

1. SCHOLAR TEAM INTRODUCTION

Two years ago, the Electrical and Computer Engineering (ECE) department at North Dakota State University (NDSU) developed the Scholar Team (ST) concept. STs incorporate the proven pedagogical techniques of vertical integration [8, 10], peer mentoring [2, 6, 9], and active and problem-based learning (PBL) [1, 7, 12] in an effort to improve the scholarly atmosphere for both students and faculty in the ECE department [3, 5].

An ST is a group of students, from freshmen to graduate students, who partner with a faculty advisor to engage in a project of mutual interest. An ST advisor rarely, if ever, lectures, and the students rarely, if ever, sit passively. Learning is accomplished on an as-need basis. For both faculty and students, ST participation is voluntary.

Each ST is given significant flexibility for self-governance: topic choice, enrollment limits, meeting times, budget decisions, and other such details are decided individually by each ST. The apparent lack of rules is crucial to ensure broad participation from both faculty and students, to encourage creativity, and to offer an experience that is completely unlike traditional classroom lectures. Still, all STs share certain features and expectations:

- Any ECE ST is open to any ECE student, freshman to graduate, and participation is voluntary.
- Each ST is housed in the advisor's research lab, where STs should meet as a group at least weekly. Students are issued keys to ensure 24-hour a day lab access.
- While students may sign up for one-credit of pass/fail ST credit per semester, such credits currently do not count toward ECE graduation requirements.
- STs should engage in scholarly activity, and students should contribute at least three hours effort per week.
- Each ST must produce a yearly technical report.
- Each ST in good standing is provided an operating budget proportional to its enrollment.
- ST activities can serve multiple purposes, including contribution to research or senior design projects.
- Unlike most traditional courses, ST activities may, and likely should, span multiple semesters.

2. SCHOLAR TEAM IMPLEMENTATION

In order to secure the necessary resources (members, space, and money) for ST implementation, the ECE department undertook some rather unorthodox steps:

- At least once per year, the department holds compulsory "town hall" meetings to discuss critical department issues with the student body. During these meetings, ST opportunities are described to students. Additionally, the department Web site assists with ST recruitment [11]. Perhaps the most effective recruiting methods, however, are individual faculty efforts and word-of-mouth between students.
- Prior to fall 2004, not every faculty member possessed a dedicated research area in the space-constrained ECE department, a fact that precludes full faculty ST participation. Thus, ECE department floor space was completely reallocated to ensure $\approx 330\text{ft}^2$ individual research space for each faculty member. Our previously centralized senior design laboratory and resources were distributed among faculty research space. The result ensures interaction between graduate-level researchers, senior design students, and ST participants; the resulting student diversity particularly encourages peer mentoring.
- In most cases, STs produce physical devices or require specialized resources. Funding is therefore a key to ST success. By using program fee resources, each ST is allocated $75 per student per semester for team activities. This committment represents roughly 25% of a student's current $656 yearly student program fee. ST funding is contingent upon satisfactory completion of all reporting requirements. A dedicated department wiki page provides a venue to publish, maintain, and distribute individual ST information, including technical documents.

In an effort to continue promoting the ST concept, plans are in development to hold a yearly scholar team day, similar to traditional career days or our senior design review day, where STs will publicly showcase their work, discuss future goals, and recruit new members.

To appear in *4th IEEE Workshop on SP Education, Sept. 24-27, 2006, Jackson Lake Lodge, Wyoming*

3. TWO-YEAR RESULTS

A wide range of STs are offered within the NDSU ECE department. The STs active in spring 2006 include 1) brain-computer interface, 2) video streaming of technical seminars, 3) ventricular assist device (VAD) and impedance control, 4) embedded systems/autonomous vehicle, 5) digital signal processing, 6) power conversion for renewable energy sources, 7) time reversal signal processing, 8) power economics, 9) aircraft lightning simulator, 10) NASA physiological sensors, 11) elastance catheter, 12) wi-fi positioning, 13) biophotonics, and 14) RF, microwave, and lightwave Design. The diversity in topics helps ensure broad appeal to the student body, and the relatively large number of teams helps keep team size small and personal.

When STs were first offered during the fall semester 2004, 13 of 15 faculty advised a ST, yielding a faculty participation rate of 86%. Approximately 100 students participated at that time, which represents approximately 20% of our student body. Individual ST membership typically varies from just a few students to nearly 20. Participation rates during following semesters have been similar. During the recent spring semester 2006, faculty participation was 71% and more than 70 students were active ST members.

During the December 2004 senior exit interviews, graduating seniors unanimously voiced support for the ST experience. A quote often heard was, "I'd be a better engineer now if I had been on a Scholar Team for four years." Later senior exit interviews and student surveys convey a similar message.

A formal but voluntary ST assessment survey was administered at the end of the spring semester 2006. Some highlight results of the survey include:

- The vast majority of respondents were acquainted with the ST concept (62/63=98%).
- A large percentage of respondents had participated on a ST (51/63=81%).
- Of those who participated, a large percentage participated more than one semester (38/51 = 75%).
- Most respondents find ST participation a good use of their time (37/51=73% strongly agree or agree, 10/51=20% neutral, and 4/51=8% disagree or strongly disagree).
- Strong majorities are satisfied with their ST experience (38/51=75% strongly agree or agree, 8/51=16% neutral, and 5/51=10% disagree or strongly disagree).
- Nearly all respondents believe ST activities are good for the department (51/53=96% strongly agree or agree, 2/53=4% neutral, and 0/53=0% disagree or strongly disagree).
- Most respondents have recommended other students participate on STs (45/57 = 79%).
- Strong majorities support the use of student fee money to fund ST activities (53/59=90% strongly agree or agree, 4/59=7% neutral, and 2/59=3% disagree or strongly disagree).

Although two years is insufficient to assess long-term results, STs are likely to provide long-term benefits. Some students who participated on STs as undergraduates are continuing for a graduate degree; at least one student has indicated that the ST experience was a factor in the decision to pursue graduate study. ST participation also builds a sense of community not easily achieved in a traditional classroom setting. Promoting a sense of belonging or community is a frequently cited strategy to improve student retention rates. Thus, STs are likely to positively impact student retention.

4. THE DSP SCHOLAR TEAM

Prior to recent initiatives and despite strong industry demand, our ECE graduates were not obtaining many of the skills required of competent DSP engineers. The addition of a hardware-intensive DSP course in 2002 offered improvements; however, students still met with little or limited success in developing DSP-based systems from scratch, particularly evident during the senior design sequence.

The primary goal of the DSP ST is to develop, from the ground up, a useful DSP system, including both hardware and software components. In meeting this goal, DSP ST participants 1) improve their DSP competence, particularly from a hardware perspective, 2) increase their awareness of DSP-related applications and research, 3) develop industry-marketable design and tool skills, and 4) hopefully have fun.

Figure 1 depicts the "Signal Processing and Acquisition Laboratory" which is utilized by the DSP ST. Notice that the DSP ST shares space with graduate students (GS) and senior design (SD) groups, an arrangement that encourages student interaction. All groups share a common laboratory printer (P), soldering station, conference table, dry erase board, and telephone. The concentration of these students, who all share an interest in signal processing, promotes a sense of community and camaraderie; from freshmen to graduate researchers, these students get to know and help each other.

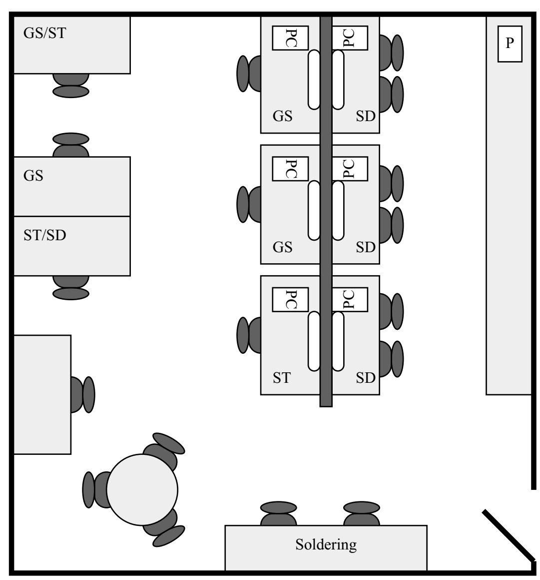

Fig. 1. Signal processing and acquisition laboratory.

Begun in 2004, the DSP ST has operated continuously over the past four semesters. Student participation has been

12, 11 (one loss due to co-op), 19 (gain of eleven, loss of three including one co-op), and 12 (gain of two, loss of nine including four graduations) for the four respective semesters. With these numbers, the DSP ST is among the largest and longest running in the ECE department.

Over the past two years, the DSP ST has developed a general DSP system (see Fig. 2) suitable for CD-quality audio applications. The DSP ST built a digital equalizer using this board. The DSP ST board is based on a Texas Instruments (TI) TMS320F2812 DSP, a TI PCM3003 audio codec, and various supporting circuitry components. The 2812 processor provides a good entry into the TI DSP line and tools at reasonable complexity, and supports in-circuit programming through a JTAG interface. To assist in this latter task, a Spectrum Digital XDS510 JTAG emulator was purchased with available ST funds. ST funds also supported the purchase of a dedicated PC for use by all participants, printed circuit boards (PCBs), and necessary components.

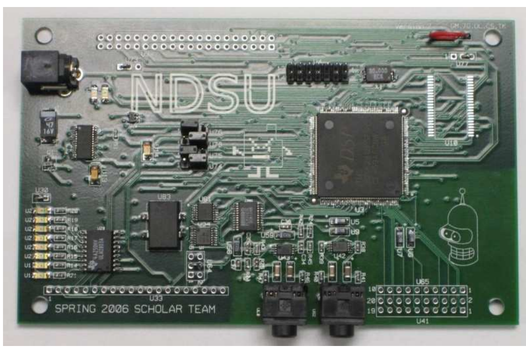

Fig. 2. NDSU ECE DSP ST PCB.

The DSP ST accomplishes most tasks using sub-groups. In critical areas, however, every team member contributes. For example, for each PCB prototype, each team member is responsible to assist in board population. During PCB layout, every team member learned to create a part using Mentor Graphics Expedition. While the current DSP ST PCBs are created using Mentor Graphics Expedition, the complexity of this package makes it difficult to learn. In spring 2006, DSP ST members evaluated the Cadence package as well as PADS, a simpler package from Mentor Graphics. Future design revisions will likely utilize PADS.

Many design steps required significant learning on the part of all participants. Most knew little about the selected parts, had minimal design experience, and lacked sufficient knowledge of the tools needed to complete the project. For example, most participants had never used Mentor Graphics, no team member had ever designed a DSP system from scratch, few members had programmed a DSP using TI's Code Composer Studio Integrated Development Environment, and no team member had ever used a JTAG interface for in-circuit programming. The combined ST features of problem-based learning, peer mentoring, and vertical integration all contribute to the successful outcome of a working board.

Some typical features of PBL, cooperative learning, and vertical integration and the corresponding DSP ST features, in italics, are enumerated below.

- Problems are designed to emulate real-world problems.
  The DSP ST audio system is a real-world application.
- Problems are complex and cover multiple objectives.
  DSP ST projects require functional knowledge of analog and digital signal processing, digital design, circuits, electronics, embedded systems, assembly and C programming, PCB design and layout, soldering, power management, packaging, testing and debugging, and others.
- Problem is introduced first, before learning occurs.
  The overall DSP ST project is published and known before members join the team. The general DSP ST objectives are established at the start of each semester, well before work begins on a solution.
- Learning procedures, facts, and concepts occurs within the context of finding a solution to the problem.
  The DSP ST exists and functions to design and build a useful DSP system, not to satisfy lecture or course syllabus requirements.
- Specific procedures or algorithms are learned as needed.
  DSP ST members learn required concepts and skills when needed during the system design, fabrication, and testing process.
- Additional structure for learning is proportional to the experience level of the learner.
  DSP ST members range from freshmen to graduate students. Senior and experienced students naturally gravitate to and assume leadership roles.
- Much of the structure for learning is provided through in-depth questioning by the instructor.
  On a rotating basis, DSP ST members lead weekly meetings, where team members report progress, discuss concepts, ask questions, and make necessary requests. All members serve as an "instructor". The DSP ST advisor offers suggestions and guidance to ensure team activities remain on track.
- Students work in cooperative or collaborative groups to gain multiple perspectives on possible solutions.
  Cooperation is required on many levels. Due to system complexity and team size, members organize into sub-groups based on interest, need, and competence. As much as possible, sub-groups include individuals distributed from freshman to graduate.

4.1. DSP ST and SD Collaboration

Three DSP ST students joined together to form a senior design group in the fall of 2005. In collaboration with the DSP ST, these students utilized the DSP ST audio board to design a stand-alone probabilistic music generator. The completed system is shown in Figure 3.

The probabilistic music generator uses second-order Markov chains to guide note transitions in a manner that is pleasing to the ear. Users navigate menus displayed on an LCD display using a four button interface. The menus provide various options, including instrument choice for the digitally synthesized output. All sound is produced at a CD-quality 44.1kHz sampling rate and 16-bits.

Figure 4 shows inside the probabilistic music generator enclosure. A DSP ST PCB, shown in figure 2, is clearly

Fig. 3. Probabilistic music generator.

present in Figure 4. The small daughtercard PCB mounted on top of the DSP ST PCB contains circuitry for system power, LCD control, and button interface.

Fig. 4. DSP PCB with daughtercard and support circuitry.

The probabilistic music generator is one of first NDSU senior design projects to successfully integrate a sophisticated DSP using custom PCBs designed from the ground up. Without leveraging off the DSP ST, such a project would likely not have been successfully completed.

5. CONCLUSIONS

During our two-year trial, ST participation and successes have exceeded our original expectations. Student and faculty feedback has been overwhelmingly positive. Further, STs have produced a variety of tangible benefits such as improved performance in senior design, increased interest in research and graduate school, project management experience, and increased awareness and contribution to current research areas.

6. ACKNOWLEDGEMENTS

I would like to thank Dr. Daniel Ewert, chair of the NDSU ECE department, who has been a driving force in the creation of the ST concept; without his leadership, department-wide ST implementation would have been impossible. I would also like to thank Dr. Mark Schroeder, who was kind enough to share a portion of the data from his ST assessment survey.

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